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UNITED STATES BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

BLASTING PRACTICES AND EXPLOSIVES ACCIDENTS IN UTAH COAL MINES

BY

D. J. PARKER

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By D. J. Parker[2]

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INTRODUCTION

The ease of ignition and violence of explosion of Utah coal dusts, together with the large volumes of methane given off in some of the mines of the State, made it imperative to abandon obsolete equipment and obviously hazardous practices for up-to-date equipment and safer methods of mining if reasonable progress were to be attained in fire and explosion prevention.

Although much can still be done to improve safety conditions in Utah coal mines, considerable progress has been made in the past 10 years.

The fundamentals of such progress include increased use of permissible electrical equipment in gassy mines, closed lights, rock-dusting, more liberal use of water at the face, better ventilation, permissible explosives fired electrically both within and without the mine, partial inhibition of blasting while the shift is in the mine, 100-percent first-aid training, increased supervision and inspection, and mass safety meetings.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6837."

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Virtually all small or "wagon" mines, chiefly those with relatively shallow workings of the so-called nongassy type, still cling to open lights and black blasting powder.

Many other coal mines of the United States also use black blasting powder and open lights notwithstanding the numerous hazards incident to their use and contrary to the teachings and recommendations of the United States Bureau of Mines and of others who have the real well-being of the coal miners of the United States at heart. As with rock-dusting, lighting, and other meritorious safety measures and equipment, the coal-mining industry as a whole has been slow to adopt safer and more economical methods of blasting.

The use of black blasting powder in Utah coal mines is limited, and its use for blasting in any mine is absolutely inexcusable, whether in Utah mines or those of any other State in the Union, and must of necessity invite disaster.

Between 5 and 6 percent of all fatalities in coal mines of the United States have been caused directly by explosives; at times Utah has been a far too generous contributor to this record, responsibility for which no one is willing to assume.

On May 1, 1900, 200 or more men were killed in Utah's greatest coal-mine disaster, following an explosion initiated either by blasting while the shift was in the mine or by the ignition of a quantity of black blasting powder by an open light. Again, in 1930 six fatalities in Utah coal mines resulted directly from explosives; the details of explosives accidents will be discussed later.

ACKNOWLEDGMENT

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BLASTING METHODS

The introduction into Utah coal mines of permissible explosives, fired electrically, has been one of the most progressive steps toward increased safety, and the industry is to be commended therefor. It is believed that no coal-producing State equals and certainly none surpasses Utah in safety in blasting practices.

Electrical blasting has been in effect in some Utah coal mines for more than 40 years and in all of the larger Utah coal mines since 1924; comparatively few accidents have resulted from the use of explosives in these mines.

Before July 1, 1924, some Utah coal mines blasted whenever occasion demanded, while the entire shift was underground, the miners firing their own shots at any time during the shift. For many years several coal mines have fired all shots electrically from the surface while all persons, including shot firers, were out of the mine.

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As the result of a conference of company officials, the Utah Industrial Commission, and representatives of the United States Bureau of Mines the following rule was adopted in 1924:

> In all coal mines in Utah in which 3 or more men are employed on any 1 shift, all shots shall be fired electrically by authorized shotfirers when all men, except the shotfirers, are out of the mine.

This rule, as well as that requiring the use of permissible explosives in permissible quantities which was formulated at the same time, is now part of the State regulations with the force of State law, but in 1932 a ruling was issued authorizing blasting by Cardox during the working shift and in 1934 was confirmed after a public hearing by the Industrial Commission.

Since 1924 two principal methods of electrical blasting have been employed - firing all shots simultaneously from the surface with all men, including shot firers, out of the mine and firing one or more shots at a time by means of a battery or blasting machine with shot firers underground. The advantages and disadvantages of these two methods have been discussed widely; the apparent tendency in late years is to favor the latter method, with the shot firers underground, largely for reasons of economy in connection with mechanized mining though obviously more hazardous.

The data presented here compare the two methods of blasting, emphasize the safer and more economical one, and at least by inference call attention to the hazards of the less safe one.

The practice of allowing miners to blast at any time during the shift, with 3 or more men underground, is illegal at present, except when blasting with Cardox, and is unquestionably more hazardous and probably in the long run more expensive than either of the 2 methods of blasting now employed by most of Utah's larger mines.

SURFACE FIRING.

The method of firing electrically from the surface by means of a master switch is essentially as follows: Firing lines are installed from the source of power on the surface to within a short distance of the working face and, as a rule, the conductors are well-insulated; further protection is afforded by several switches, including the gap-switch section or entry switches and place switches.

One type of gap switch consists of pieces of heavy wire or copper bars, approximately 6 feet long and preferably of unequal length, installed in the main firing circuit inside the mine but comparatively near the surface; this serves as an additional precaution to prevent power from entering the mine accidentally through the firing circuit, and the wide gap is a safeguard against high-voltage current - lightning, for instance - which might jump the gap of an ordinary switch.

Another type of gap switch in use is made by soldering sockets with flattened ends on the ends of the two main conductors. The gap is closed by inserting the flattened ends of the sockets into their respective contacts, to which are connected the outby sections of the main circuit leading to the master switch. When not in use the free ends of the 2 wires are disengaged from the contacts, bent backward, and locked in place, thus making a 5- or 6-foot gap in the main firing circuit. This switch is likewise underground but comparatively near the surface.

A third type of gap switch, used exclusively at one mine, is in the form of a gate made up of 1-inch pipe. The gate is supported by a 3-inch-piece timber set, and the wiring extends from 2 insulated contacts on the unhinged side of the gate through horizontal members of the gate to an intervening double-pole knife switch and thence to the master switch. When the gate is closed the contacts engage the terminals of the main underground firing circuit. When not in use the gate is locked in the open position. It is located in the manway about 50 feet from the surface; in addition to serving as a gap in the main blasting circuit, when closed it prevents access to the mine through the manway before blasting.

The section switch, which controls shooting lines of one or more panels or entire entries, makespossible the isolation of any section of district of the mine and also acts as an additional safeguard against stray currents.

The room switch is in the entry near or possibly just inside the room neck. Lines of relatively small-diameter insulated wire are strung from this switch to the face for the day's blasting; no. 10 wire is used on entries and no. 14 wire in rooms.

All wires and switches should be installed properly on insulators, and the supports holding them preferably should not carry any other source of electric current; some mines, however, make use of ordinary power lines, with relative safety, by properly installed switches and the enforcement of strict regulations concerning their use.

Shot firers load and tamp the holes, connect the wires, close the several switches (at least three separate switches), and at the end of the shift, blast by means of a master firing switch on the surface after all men, including themselves, are out of the mine. When the mine is reentered to inspect the shots the switches are opened in the reverse order, and all switches except room or place switches are locked securely.

If the permissible limit for explosives has not been exceeded, if the proper precautions have been observed in the installation and maintenance of the system, and if reasonable care has been exercised in loading, tamping, and placing holes the possibility of the occurrence of a fire or an explosion is remote; there certainly is no likelihood of injury to a workman and no chance of any extended disaster with heavy loss of life where the above system is installed and used carefully.

In blasting from the surface in the coal mines of Utah two types of master switches are used - the ordinary double-pole knife switch and a time-limit switch of the solenoid type. The latter type comprises three switches. The main switch is of the 2-pole type; before closing it, a plunger operating in a slotted 1-inch pipe is raised to the top of the slot and connected to the solenoid switch, which automatically releases the plunger when the 2-pole switch is closed. The plunger drops 6 feet 8 inches and opens a single-pole switch, thereby breaking the main circuit in case the 2-pole switch is still closed; it is therefore impossible to maintain the current on the firing circuit for a longer period than that required for the plunger to fall - 0.645 second or 645 milliseconds, without taking friction into consideration. The current therefore remains on the firing circuit during this time.

The question, on which there is little authentic information, has often been raised concerning the minimum time required for an electric current to remain on the blasting circuit and yet fire the shots. The Bureau of Mines recently tested a number of shot-firing units equipped with a special interior timing device which would allow the current to flow for approximately 5 milliseconds (0.005 second). Five timing tests made on each of 10 different machines showed a variation in the average timing of each machine of 4.31 to 6.60 milliseconds, although the timing for any individual machine was rather close to the average. These machines were designed to fire a maximum of 10 electric blasting caps in series. Two trials were made with one of the machines, which had a timing of 4.31 milliseconds. Five electric blasting caps were used in series in each trial, with 60 ohms added resistance; there were no misfires. A particular electric blasting cap, arbitrarily designated as G, was used in these tests. The electric blasting cap which fired 22 milliseconds after the current was applied was the first of the 10 to fire in the 2 trials. However, it should be remembered that there were 60 ohms added resistance, while in many shots fired within the mine the resistance is very much less.

Other tests indicated that with a very low line-resistance these G electric blasting caps would fire somewhat sooner - in about 7 milliseconds. This combination of a shot-firing unit, which cuts the current off the line in about 5 milliseconds, and of the G blasting caps, which under the most severe conditions - that is, with minimum resistance in the line - will not fire until about 7 milliseconds have elapsed, is very desirable because the voltage is off the shot-firing lines before the shot fires; therefore, no contact of the cap wires, the connecting wires, or the shot-firing cable can result from the blast at the face while there is voltage on the line.

Several types of electric blasting caps have been tested by the Bureau of Mines. None of them except the G has a lag exceeding 5 milliseconds, and few even approach it; that is, they all function much faster than the G.

These data cannot be readily translated directly into firing a large number of shots simultaneously outside the mine, but they indicate definitely that electric blasting caps can receive enough energy in an exceedingly brief time with a very moderate current - certainly much less than 1.5 amperes. This information should be valuable in a thorough study on the reduction of the time of application of the firing current as now used in the coal mines of Utah. The time-limit shot-firing switch mentioned previously permits the current to remain on the firing circuit for 645 milliseconds. With the ordinary-type 2-pole master switch the current is applied to the firing circuit for approximately the same length of time, depending somewhat on the agility of the operator. These tests indicate that if enough energy can be given to an electric blasting cap in 5 milliseconds (0.005 of a second) the same principle can be applied to blasting from the surface in Utah coal mines.

The author realized that there is considerable difference between firing in series, as in the foregoing tests, and firing in parallel; when blasting caps are fired in series the same current passes through each bridge of each electric blasting cap, and when fired in parallel the current flowing through the different bridges may vary substantially. Most assuredly the current will vary substantially if the parallel circuits are unbalanced, as they would be normally, because there may be much more resistance in one circuit, which determines the amount of current passing through one bridge of a cap, than in another circuit, which determines the amount of current passing through another bridge, perhaps in another and more remote section of the mine. There remains the difficulty, however, of making and breaking contact with currents of much higher values than were used in these experiments. Alternating current at 180, 220, and 440 volts potential is now used in firing circuits when blasting is done from the surface.

UNDERGROUND FIRING

With shot-firers underground the shots are fired by a battery or blasting machine of the magnetic type, one or more holes being fired at one time. Several hazards attend this method of blasting, although it is much safer than any blasting method permitting the miner to blast as he desires.

GENERAL PRACTICES

Although far from perfect, practices in the storage, transportation, and use of explosives in Utah coal mines are for the most part commendable; from a safety point of view few States equal and none surpasses Utah. This is especially true of the larger producers.

In detailing some of the more important explosives practices common to the coal mines of Utah consideration is not given to the small or "wagon" mines, which produce only about 6 percent of the State's output.

As a rule, magazines are substantially constructed of masonry, maintained free of accumulations of debris, well-ventilated, and with no electric wiring. With few exceptions they are located in compliance with provisions of the American Table of Distances (1919 revision). Explosives are transported into the mine in well-constructed and thoroughly insulated boxes carried in insulated mine cars painted red and conspicuously marked and also brought in by the miners in canvas and rubberized fabric bags. Detonators are carried into the mine in special containers provided for that purpose by shot firers who usually walk into the mine. Wooden tamping bars and inert stemming (clay or

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adobe) are used. The rules are that shot firers inspect the faces for the presence of methane before and after blasting, and the face regions are wetted before blasting. In most mines the shot firers inspect the shot holes for depth, direction, and size before loading; such desirable inspection by trained shot firers is impossible where the miners load and tamp the holes. Preferably all shot holes should be inspected, loaded, tamped, stemmed to the collar, and wired as well as shot by shot firers.

In loading holes it is customary to place the first stick flush with the collar, shove this stick ahead with the second, and then place the third stick in the hole flush with the collar. The three sticks, including the primer, constituting less than the permissible limit of 1-1/2 pounds per charge, are then "pushed home" with the tamping bar. Pushing the entire charge home in one operation is fairly adequate insurance against possible gaps between the sticks of explosive due to drillings that may not have been removed from the hole; the chances of a partly exploded charge are thus reduced materially.

Primers are made by inserting the detonator full length into the side of the cartridge on an angle so that as far as is feasible the loaded end is about on the axial line and directed toward the bulk of the charge when placed in the shot hole. The detonator is secured to the cartridge by taking a half hitch around the latter with the leg wires. Shot firers of long experience claim that by this method there is much less likelihood of damaging the insulation of the leg wires by tamping than where the detonator is embedded in the end of the cartridge on the axial line. Furthermore, in side priming there is less danger that the detonator will pull out of the cartridge during the tamping than in end priming with the wrapper tied around the leg wires.

In the majority of Utah coal mines the three systems of wiring shots are series, parallel, and parallel-series, the two latter methods predominating. The method in use at any particular mine apparently is based on the results of considerable experience and perhaps to some extent on personal preference. Regardless of the method used, the desired results probably are attained if judged by the percentage of missed shots. Theoretically, straight series should be the most efficient method of wiring shots; however, the proponents of the other methods, especially the straight parallel, present some convincing evidence from a practical standpoint.

Missed shots ordinarily are handled by first attempting to fire each charge by a blasting machine, with no one underground except the shot firers. If the shot again fails to explode a parallel hole is drilled, generally under the personal supervision of the foreman, a safe distance from the missed hole and fired on the following shift. Meanwhile the detonator leg wires are disconnected from all wiring, "shorted" by twisting the ends together, and tucked into the collar of the missed hole. The location of a missed hole is identified by a suitable marker, usually a piece of white paper protruding from the collar.

If the charge in the parallel hole does not explode the charge in the missed hole, as is sometimes the case, it is decidedly hazardous to pick or shovel into the loose coal, especially where mechanical loading is employed. However, diligent effort is made to locate the cartridges from the missed hole.

An instance is on record where an electric detonator was included in a domestic shipment of coal from a Utah mine to an adjoining State. When some of this coal was placed in a cookstove the detonator exploded, severely injuring one person; in consequence, the company making the shipment became the defendant in a heavy damage suit.

Another method of handling missed holes, employed to a very limited extent, is to wash the stemming out through a nonsparking pipe attached to a hose and then remove the charge. The primer and any cartridges outby may be pulled out by the detonator legs, and any remaining explosive can be removed with a wooden stick sharpened at one end. If the wrappers of the cartridges, other than the primer, are slit before loading, the charge may be washed out. After removal from the missed hole the explosive is taken to the surface and disposed of safely.

ANALYSIS OF EXPLOSIVES ACCIDENTS

Information has been obtained on all reported accidents (fatal and nonfatal) involving loss of time of more than 1 day due to explosives or their use or misuse for the 15 years 1919-33.

Data were available on 19 of the larger producing companies, which are representative of the State; for the most part, those not listed were small, intermittent producers.

Table 1 gives the tonnage produced during this period, or for those portions of the period during which the particular company operated, the number of fatal and nonfatal accidents caused by blasting or explosives, and the rates per million tons produced for fatal and nonfatal blasting or explosives accidents figured separately for each company. Data for the companies that now or formerly blasted from the surface with all men including the shot firers out of the mine and for those that blast with shot firers only underground are grouped in two periods - 1919-24 and 1925-33. The reason for the division into periods is that during 1924 blasting with the shift underground was prohibited and blasting from the surface was not introduced into some mines until about the latter part of 1924 or early in 1925. During 1924 electrical blasting was adopted by all companies shipping by rail, while the small or wagon mines apparently were exempted.

Some companies show a marked increase in the accident rates for the second period over those for the first, especially where they had no accidents in the first period and one in the second. Accidents attributable directly to explosives are so rare in the State that an attempt to tabulate the rates by years for individual companies, unless exceptionally large, gives a rather irregular result; however, when rates for the entire State for these two periods are compared a marked decrease is evident for the period during which all blasting was done with the shift out of the mine compared with the period when blasting was done in some mines with the working shift in the mines.

caused by blasting or explosives

Company	Period of operation	Total coal production, tons		Fatalities		Deaths per 1,000,000 tons produced		Number injured		Injured per 1,000,000 tons produced	
		1919-24	1925-33	1919-24	1925-33	1919-24	1925-33	1919-24	1925-33	1919-24	1925-33
Blasting from surface											
Columbia Steel Corporation	1924-33	301,528	2,956,753	0	0	0	0	1	0	3.31	0
Liberty Fuel Co.	1919-33	995,906	1,581,136	0	0	0	0	2	0	2.01	0
Royal Coal Co. 1	1919-33	1,071,260	1,065,852	0	0	0	0	0	1	0	0.93
Spring Canyon Coal Co.	1919-33	2,287,258	3,509,595	1	0	0.44	0	3	3	1.31	.85
U. S. Fuel Co.	1919-33	6,135,321	6,445,880	0	2	0	0.31	9	2	1.47	.31
Utah Fuel Co. 1	1919-33	8,104,421	5,934,909	2	0	0.25	0	8	0	.99	0
Total and average		18,895,694	21,494,125	3	2	.15	.09	23	6	1.21	.27
Blasting from underground											
Blue Blaze Coal Co.	1926-33	0	1,399,645	0	3	0	2.14	0	2	0	1.42
Carbon Fuel Co.	1919-6/30/30	1,236,674	801,934	0	0	0	0	1	2	0.81	2.49
Chesterfield Coal Co.	1924-33	91,787	785,057	0	0	0	0	0	1	0	1.27
Grass Creek Fuel Co.	1919-6/30/29	156,011	73,297	0	0	0	0	0	0	0	0
Independent Coal & Coke Co.	1919-33	2,313,087	4,029,257	0	0	0	0	2	3	.86	.74
Kinney Coal Co.	1919-25	548,346	64,967	0	0	0	0	0	0	0	0
Lion Coal Co.	1919-33	1,078,344	795,392	0	0	0	0	0	1	0	1.25
MacLean Coal Co.	1925-33	0	141,533	0	0	0	0	0	0	0	0
Mutual Coal Co.	1922-33	513,445	1,037,921	0	0	0	0	4	0	7.79	0
Peerless Coal Co.	1919-33	935,290	961,686	0	0	0	0	0	1	0	1.03
Scofield Coal Co.	1919-33	467,754	412,724	0	0	0	0	5	0	10.69	0
Standard Coal Co.	1919-33	1,973,205	2,666,058	3	0	1.52	0	10	2	5.07	.75
Weber Coal Co.	1919-6/30/29	178,613	167,596	0	0	0	0	0	0	0	0
Total and average		9,492,556	13,337,067	3	3	.31	.22	22	12	2.31	.89

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[1] The Royal Coal Co. and the Utah Fuel Co. discontinued surface blasting on or about June 30, 1929, and January 1, 1929, respectively.

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The death rate per 1,000,000 tons for the first group of companies (those blasting from the surface) for the period 1919-24 was 0.15 compared with 0.09 for 1925-33. Likewise the injury rates per 1,000,000 tons for the two periods were 1.21 and 0.27, respectively.

The fatality rates for the second group of companies (those blasting from underground) for the two periods were 0.31 and 0.22 and the injury rates 2.31 and 0.89, respectively.

Table 2 gives the accidents attributable directly to explosives, tabulated according to cause. These causes have been divided into 13 classes. The first 7 classes form a group of accidents that might happen regardless of the method of blasting; the last 6 are due directly to the method of blasting and are unlikely to occur if blasting is done from the surface.

Where surface blasting is employed the general practice in case of missed holes is to disconnect all wiring, mark the holes, and blast them from the surface on the succeeding shift. This procedure, however, is not always followed; in some instances shot firers fire missed holes with a blasting device before the shift enters the mine.

Regardless of the type of electrical blasting employed, there is always the possibility of a premature shot from stray currents, improperly made primers, or tamping the shot too vigorously.

When surface blasting was introduced in the different mines is not known definitely; accidents from unguarded or premature shots were possible early in the second period (1925-33) before this method of blasting was adopted.

The total number of accidents for 1919-24, before the adoption of electrical blasting and at a time when shooting during the working shift was common in some mines, was 51 compared with a total of 23 in 1925-33.

During 1925-33 the 6 companies blasting from the surface produced 61 percent of the tonnage and can be charged with only 34 percent of the accidents. Moreover, some of the accidents occurred in mines that blasted during the shift; the company operating these mines used surface blasting in most of its properties.

Six of the 12 fatalities during the 15 years 1919-33 occurred in 1930, which had by far the worst record for any year covered by this report.

Table 1 lists only 11 fatalities, although 1 fatality not recorded in the table occurred in 1930 in a wagon mine. Wagon mines produce approximately 6 percent of the State's tonnage, and with only the 1 fatality their explosives-accident record has been unexpectedly good.

Of the 6 fatalities in 1930 the first 2 resulted from the same accident. An entry was being driven through a rock fault several hundred feet in width; after a round of shots had been blasted the men were digging in the loose rock when some loose explosive was struck by a pick and detonated. In addition to

Company	Accidents from handling							Accidents from blasting							
	Transportation	Charging	Suffocation	Drilling into old holes	Striking into loose rock or coal	Thawing	Detonators	Unguarded shots	Returned too soon	Premature shot	Sparks from match lamp or candle	Delayed blast	Shot breaking through rib or pillar	Total	Grand total, 1919-33
1919-24															
Columbia Steel Corporation												1		1	
Liberty Fuel Co.												2		2	
Royal Coal Co.														0	
Spring Canyon Coal Co.									1		3			4	
U. S. Fuel Co.					1		3	2				1	2	9	
Utah Fuel Co.	1	1		2			1	2	1	1	1			10	
Blue Blaze Coal Co.														0	
Carbon Fuel Co.									1					1	
Chesterfield Coal Co.														0	
Grass Creek Fuel Co.														0	
Independent Coal & Coke Co.										1	1			2	
Kinney Coal Co.														0	
Lion Coal Co.														0	
MacLean Coal Co.														0	
Mutual Coal Co.								1	2			1		4	
Peerless Coal Co.														0	
Scofield Coal Co.									3			2		5	
Standard Coal Co.			1	1					6			1	4	13	
Weber Coal Co.														0	
Total	1	1	1	3	1		4	5	14	2	5	8	6	51	

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TABLE 2. - Classification of fatal and nonfatal explosives accidents--Continued

Company	Accidents from handling							Accidents from blasting						Total	Grand total, 1919-33
	Transportation	Charging	Suffocation	Drilling into old holes	Striking into loose rock or coal	Thawing	Detonators	Unguarded shots	Returned too soon	Premature shot	Sparks from match lamp or candle	Delayed blast	Shot breaking through rib or pillar		
1925-33															
Columbia Steel Corporation 1														0	1
Liberty Fuel Co. 1														0	2
Royal Coal Co. 1								1						1	1
Spring Canyon Coal Co. 1		1		1						1				3	7
U. S. Fuel Co. 1		1			3									4	13
Utah Fuel Co. 1														0	10
Blue Blaze Coal Co.				5										5	5
Carbon Fuel Co.				1				1						2	3
Chesterfield Coal Co.	1													1	1
Grass Creek Fuel Co.														0	0
Independent Coal & Coke Co.				2		1								3	5
Kinney Coal Co.														0	0
Lion Coal Co.				1										1	1
MacLean Coal Co.														0	0
Mutual Coal Co.														0	4
Peerless Coal Co.									1					1	1
Scofield Coal Co.														0	5
Standard Coal Co.								1	1					2	15
Weber Coal Co.														0	0
Total	1	2		10	3	1		3	2	1				23	
Grand total	2	3	1	13	4	1	4	8	16	3	5	8	6	74	74

[1] Companies that now or formerly employed surface blasting in some or all of their mines.

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the 2 killed, 1 man was injured severely but recovered. One of the shot holes was cut off by the initial blast before the explosive was detonated, and part of the undetonated explosive became mixed with the "muck"; $1\frac{1}{2}$ sticks of explosive were found in the hole.

The second accident, which resulted in 3 deaths and 1 injury, occurred during the sinking of a rock slope. A missed hole containing 16 sticks of 60-percent straight dynamite, the presence of which was apparently unknown, was left in the bottom from a previous shift. The unbroken rock formed an obstruction to the proper extension of the track. It was then decided to drill and blast the projecting rock. Accordingly, a hole was started directly above and at right angles to the missed hole; the explosion followed when the drill struck the missed charge.

The third accident, which resulted in the death of 1 man, occurred in a small wagon mine under lease. The victim of the accident had drilled a shot hole near the top of the coal bed, which was 10 feet thick, and had charged it with 2 pounds of black blasting powder. Squibs were used to ignite the charge. Because of the height of the shot hole above the floor the deceased supposedly fastened a carbide lamp to the handle of a blasting needle and was attempting to light the squib at the tip end. Presumably the flame of the carbide lamp came in contact with the body of the squib, perhaps an inch from the end, and fired the charge before the victim had an opportunity to seek refuge from the blast.

It is interesting to note that of these 6 fatalities 5 occurred while driving through rock, which might indicate that the coal miner is less adept in such work than the more experienced metal miner. Such explosives accidents show the necessity for keen mental alertness, effective supervision, and rigid observance of the State mining laws if they are to be prevented.

SUGGESTIONS FOR REDUCING EXPLOSIVES ACCIDENTS

A few outstanding suggestions are offered to prevent explosives accidents:

1. Maintain blasting schools for educating the supervisory force, including foremen, fire bosses, and shot firers.

2. Buy explosives in such quantities that they can be used while still fresh.

3. Store explosives in a cool, dry place and in a separate magazine from detonators.

4. Use only extra-low-freezing permissible explosives which require no thawing.

5. Investigate thoroughly and report all accidents involving explosives or methods of firing.

6. Electrically short-circuit the leg wires of electric detonators by twisting or otherwise and maintain the short circuit until ready to connect to the shot-firing cable.

7. Electrically short-circuit the battery end of the shot-firing cable by twisting or otherwise and maintain the short circuit until ready to connect to the source of the electric current.

8. Test the shot-firing cable before connecting it to the electric detonator to make sure that no current is on the cable.

9. Use locked safety switches on all permanent shot-firing lines.

10. Disconnect the source of electric current from the shot-firing cable immediately after firing a blast and immediately after a misfire.

11. As a precaution against misfires maintain the permanent and temporary firing lines in first-class condition by using a high-quality insulated wire and inspect frequently.

12. Tamp all holes to the collar with incombustible material free of sharp or angular pieces.

13. As a precaution against premature explosions do not tamp explosives, primers, and stemming very vigorously.

14. Use only wooden tamping bars; they should not be shod with or have handles of metal.

15. The location of magazines should be governed strictly by the American Table of Distances (1919 revision).

CONCLUSIONS

Companies instituting methods of blasting from the surface and following them carefully and conscientiously have had noticeably low accident rates. Unquestionably at one time one or more gassy mines employing this method tended to load the shot holes beyond the limit of permissible explosives and also failed to consider depth and location of shot holes. With proper supervision and rigid discipline such obviously unsafe practices can and should be eliminated.

From an economic viewpoint some of the factors determining the advisability of surface blasting are thickness of bed, amount of methane given off, and efficiency of supervisory force. A bed of such thickness that two or more lines of shot holes are required across a face has the essence of dependent shots in all above the lower line. If the mine is gassy delay-action detonators cannot be used, and an extra brattice crew is required to replace the line canvas at the faces where all shots are fired simultaneously. If the bed is thick and the mine is classed as nongassy delay-action detonators sometimes are used in the upper lines of shot holes, line canvas, of course, not being necessary.

Where human life is involved, and unquestionably life should be the first consideration, the safest known method of using explosives to bring down coal is to blast from the surface while all men are out of the mine. A further reduction in explosives accidents could be expected if surface blasting were adopted more generally.

Although the progress of safety usually can be measured by the yardstick of costly experience much credit is due the coal industry of Utah for the adoption of the safest known blasting practices for coal mining, and any tendency toward a return to the obsolete and hazardous practice of blasting with the shift underground would be a regrettable and grave mistake, one likely to result in heavy loss not only of life but of property as well.